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DYNAMIC TESTS OF NEW TYPE FUSES FOR SHAPE CHARGE PROJECTILES OF GRENADE LAUNCHER AMMUNITION

Dynamic nondestructive testing methods for piezoelectric integrated fuses for arming one and two head shape charge projectiles of grenade launcher ammunition are described in the article. Presented results of study concern arming of fuses and resistance of their mechanical and electrical elements to overload during real shot (2600 g) *and also during laboratory tests* (1450 g)*. Tentatively calculated parameters of arming the fuse mechanisms: time mechanism, plunger of time mechanism, protective-driving plunger of primer holder, additional slide plunger (moving during second overload) were confirmed during applied tests.*

1. Introduction

A project concerning designing of heads for tandem projectile [1, 2], which may increase an assortment of grenade launcher ammunition, is conducted in Military Institute of Armament Technology (Wojskowy Instytut Techniczny Uzbrojenia,WITU).

Tandem projectiles serve for fighting against armored targets equipped with reactive cassettes. One of the most important assemblies in such projectiles is a fuse [4]. Model of fuse, to arm tandem shape charge projectiles, was designed by WITU constructors, whereas 6 copies of it were made in Electromechanical Plant "BELMA" S.A. in Bydgoszcz (Bydgoskie Zakłady Elektromechaniczne „BELMA" S.A.). The designed fuse to arm shape charge heads is a type of piezoelectric integrated fuse. Classical fuse to shape charge ammunition contains two separated parts, head and bottom. Integrated fuse contains head and bottom as one part, which is located at the back of shape charge head. Scheme for mutual location of fuse mechanical elements is shown on the Fig. 1 and 2.

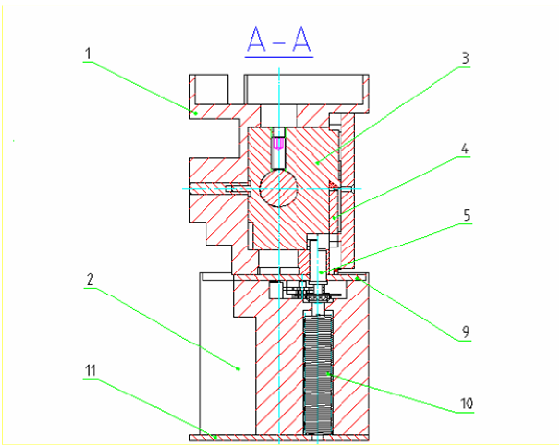


Fig. 1. Scheme mutual location of fuse mechanical elements; 1-holder of primer (rotor), 2-holder of time mechanism, 3-rotor, 4-slider, 5-lock on the wheel of time mechanism, 9-bearing plate, 10-spring of time mechanism

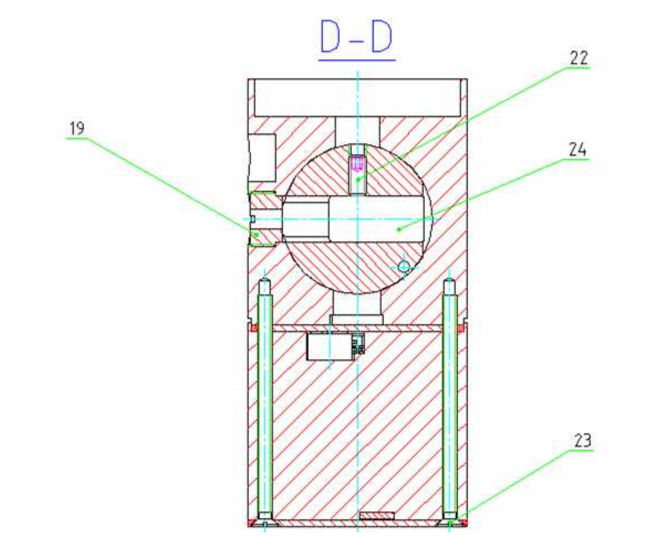


Fig. 2. Scheme mutual location of fuse mechanical elements in perpendicular plate to view A-A from Fig.1; 19-screw plug, 22-set screw, 24-primer, 23-screw

The produced models underwent indispensable static and dynamic laboratory tests, which might check in practice correct operation of the designed model. The results of mentioned above tests will be used to design a prototype. Methods and results of laboratory and firing ground dynamic tests for the integrated fuse with using inert head are described below.

2. Material and methods

2.1. Dynamic laboratory tests of integrated fuses

Dynamic tests of the fuses were performed in two stages. At first, the dynamic tests were conducted in laboratory with the application of a whirling arm, as a source of inertial force. After obtaining positive results in those tests on the whirling arm, the fuses were studied in conditions of real shots during dynamic firing ground tests.

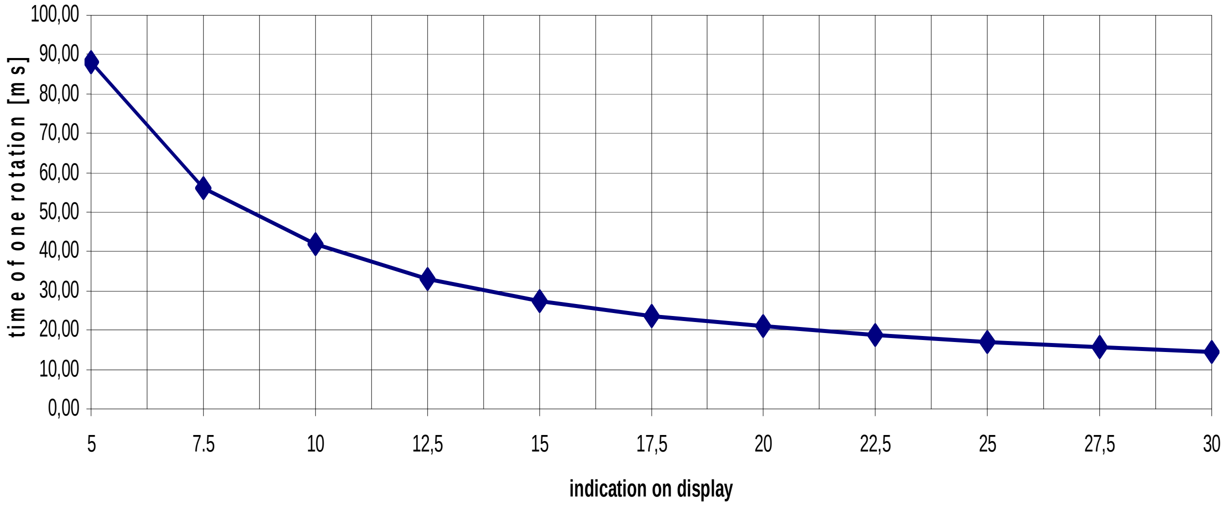
Special whirling arm was used for dynamic laboratory tests, in which inertial force affected the fuses for estimation of overload values and their arming limits. Two fuses were placed simultaneously in whirling arm on the same axis so as inertial force generated overload in analogous direction as in a real shot condition (Fig. 3 and 4).

Fig. 3. Inserting of fuse to grip in whirling arm.

Fig. 4. Pair fuses placed in whirling arm.

During study, rotation speed of whirling arm was determined with special camera, which was fast enough to record rotation. Based on this, curve of relationship between rotation speed (m/s) of whirling arm and values displayed at its controller was obtained (Table 1).

Table 1. Calibration of the whirling arm.



Obtained curve of rotation speed was used to calculate centrifugal forces and acceleration operating on the plunger, which moves a rotor (Table 2). The plunger was made in two mass variants, duralumin (*d*) and brass (*m*).

Table 2. Calculation of centrifugal forces and acceleration operated on the plunger, which moves a rotor.

Indication	Time of rotation by 360°, ms	Number of rotations n, rot/s	Mass of plunger		Average rotation radius of centre of plunger mass , *R*, m	Angular velocity, ω, rad/s	Centrifugal force,		Acceleration	
			m_a, kg	m_m, kg			C_a, N	C_m, N	a_a, m/s^2	a_m, m/s^2
5	88.00	11.36	0.00055	0.00171	0.075	71.40	0.21	0.65	382.35	382.35
7.5	56.00	17.86	0.00055	0.00171	0.075	112.20	0.52	1.61	944.16	944.16
10	42.00	23.81	0.00055	0.00171	0.075	149.60	0.92	2.87	1678.50	1678.50
12.5	33.00	30.30	0.00055	0.00171	0.075	190.40	1.50	4.65	2718.90	2718.90
15	27.50	36.36	0.00055	0.00171	0.075	228.48	2.15	6.70	3915.21	3915.21
17.5	23.50	42.55	0.00055	0.00171	0.075	267.37	2.95	9.17	5361.49	5361.49
20	21.00	47.62	0.00055	0.00171	0.075	299.20	3.69	11.5	6714.02	6714.02
22.5	18.80	53.19	0.00055	0.00171	0.075	334.21	4.61	14.3	8377.32	8377.32
25	17.00	58.82	0.00055	0.00171	0.075	369.60	5.63	17.5	10245.3	10245.3
27.5	15.80	63.29	0.00055	0.00171	0.075	397.67	6.52	20.3	11860.6	11860.6
30	14.50	68.97	0.00055	0.00171	0.075	433.32	7.75	24.1	14082.7	14082.7

Based on above results arming acceleration of selected mechanisms of fuses like: time mechanism, plunger of time mechanism, protective-driving plunger of primer holder and additional slide plunger was calculated. Selected results of arming tests for time mechanism and protective-driving plunger without slider are presented in Table 3.

Table 3. Results of arming tests of time mechanism and protective-driving plunger without slider.

Number of fuse	State of arming of time mechanism	State of arming of protective-driving plunger	Indication on display of the whirling arm	Acceleration a, m/s^2
1	yes	yes	32	>14082.7
1	yes	no	>10	>1678.5
1	no	no	<10	<1678.5
3	yes	yes	32	>14082.7
3	yes	no	15	3915.2
4*	yes	yes	20	6714
4*	yes	yes	32	>14082.7
4*	yes	no	15	3915.2
5	yes	no	15	3915.2
5	yes	yes	32	>14082.7

* -means protective-driving brass plunger

The results in Table 3 show that the time mechanisms in all tested fuses unlocked when the acceleration (a) was greater than 167 g. Protective-driving plunger was armed when the acceleration was > 1400 g (a_d) and > 670 g (a_m) for duralumin and brass plunger, respectively.

The results of arming of time mechanism and protective-driving plunger and also slider plunger are presented in Table 4. Minimal necessary acceleration to arm fuse No. 4 containing brass plunger with mass of 1.71 g (m) was 7780 m/s^2 (a). Whereas, in the fuses with duralumin plunger (mass of 0.55 g), the driving mechanisms of rotor was armed under acceleration of 1024.5÷1186 g. All time mechanisms armed when acceleration was 7780 m/s^2. The plunger springs in time mechanisms were made of 0.3 mm wire.

Table 4. Results of arming tests of time mechanism and protective-driving plunger with slider

Number of fuse	State of arming of time mechanism	State of arming of protective-driving plunger	State of arming of slider	Indication on display of the whirling arm	Acceleration . a, (m/s^2)
3	yes	yes	yes	32.5	>14082.7
4*	yes	yes	Protected position	32.5	>14082.7
3	yes	yes	yes	26.5	(10245.2; 11860.6)
4*	yes	yes	Protected position	26.5	(10245.2; 11860.6)
3	yes	yes	yes	26.5	(10245.2; 11860.6)
4*	yes	yes	Protected position	26.5	(10245.2; 11860.6)

* -means protective-driving brass plunger

In tested integrated fuses were used electric circuits, which cumulate and next transform electrical charge from pressed piezogenerator during impact of projectiles in target. Then this electrical charge is sent to high voltage disruptive detonator, which initiates shape charge head through detonator. These electric circuits were tested after each stage of production: before and after their flooding by resin and after application of mechanical hazard.

The first two tests of resistance to mechanical hazard were performed on ready for use electric circuits but not installed in the fuse body. It was dropping electrical circuits on concrete base from 12 m height and then simulation real acceleration in the whirling arm. Electric circuits, after installation into the fuse body, were put to successive hazards in the whirling arm and then two of them were fired.

Electric parameters of electric circuits didn't change after all laboratory tests and neither did after shooting. Parameters were tested with using generator of a pair of high voltage impulses. The oscilloscope was applied to measure the amplitude of output impulse and time delay of output impulse from electric circuits.

2.2. Dynamic firing ground tests with using inert head

Firing ground tests of the integrated piezoelectric fuses were curried out on the specially designed test stand, where the fuses without pyrotechnic elements (Fig. 5 and 6) were put in prepared dummy of projectile (Fig. 7) fired from grenade launcher RPG-7 to pieces of fabric placed in a metal box devoid of front wall. This way, the tests of mechanical and electrical elements of the fuse in real shooting conditions were executed.

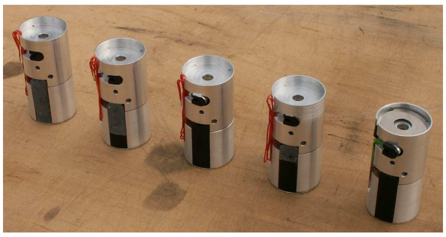


Fig. 5. Fuses without pyrotechnic and piezoelectric elements prepared for testing [5].

Fig. 6. Fuse with electric circuit prepared for testing.

The metal dummy of piezogenerator [3], in the shape of a disc, was mounted in the fuse instead of a real element. Additionally, pyrotechnic elements were disassembled before the test. Batch of 5 fuses (Fig. 5) were prepared for testing. Some of them were multiple shot, for example after changing brass driving plunger for duralumin plunger.

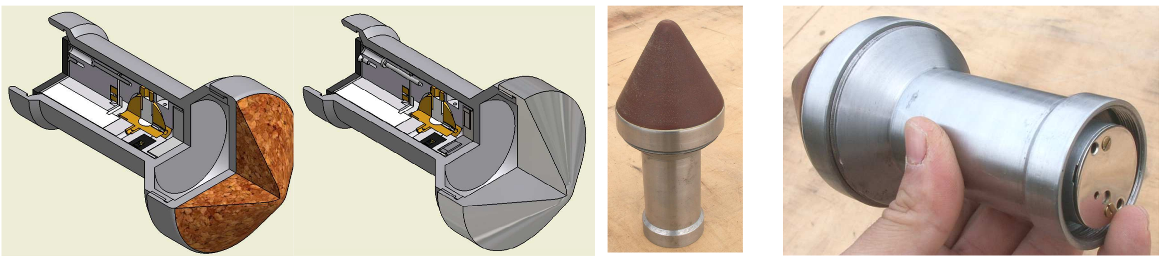


Fig. 7. Dummy of projectile (inert head) for grenade launcher. RPG-7 with placed inside integrated piezoelectric fuse.

After the shot, each projectile was slowed down by soft pieces of fabric, so that the fuse was retrieved without mechanical damages connected with target hitting (the test stand is demonstrated at Fig 8÷11). Next, the fuse was disassembled and its mechanisms were controlled if they functioned correctly or not, and checked what the reason of faulty operation was. When mechanisms and separate elements were not damaged, the fuse was mounted again in a different configuration, for example with different mass of plunger driving rotor. After that, the tested fuse was placed in the dummy for verification of correct functioning during shooting.

Fig. 8. Stand of grenade launcher RPG-7.

Fig. 9. Grenade launcher RPG-7 prepared for shooting the projectile dummy with fuse.

Fig. 10. Metal box filled with pieces of fabric.

Fig. 11. View of stand for dynamic nondestructive testing of fuses.

The distance from the top of inert head, loaded into a barrel of grenade launcher, to the front wall of the metal box with fabric was 30 m. Each fuse should be fully armed after covering such distance.

Four electric circuits were investigated regarding the resistance to overloading during the firing tests. Tested electric circuits and fuses in the projectiles dummies were multiple fired from the grenade launcher. Correctness of functioning was controlled after each test in the same way as it was described earlier.

3. The results of testing

The aim of nondestructive tests using method of firing projectiles to pieces of fabric was to check:

- correctness of fuse arming after action of two successive overloads applied ,
- resistance of mechanisms to real overloads occurring during the shooting,
- resistance of electric elements to these overloads.

The first fired fuse marked as No. 2 contained duralumin plunger, which interlocked and moved a holder of a primer. The locks were unlocking successively during the shot. However, a lock of the time mechanism returned to safety position instead of staying in an armed position. So, this lock blocked the time mechanism in unarmed position. In consequence the fuse didn't arm at all.

The second fired fuse No. 4 contained brass plunger, which interlocked and moved holder of the primer. During the shot, all safety locks were unlocking successively, but too big mass of brass plunger extended rotation time of the rotor (primer holder) and the fuse elements stopped in safety position, as if the second required overload for full arming didn't act.

The third fired fuse No. 3 also contained a duralumin plunger. In this case, the fuse fully armed after firing and it worked correctly.

The fourth fired fuse No. 1 contained a duralumin plunger interlocking and moving the holder of the primer. Its safety locks functioned correctly except for the time mechanism lock, which returned to safety position instead of staying in armed position and blocked the time mechanism. Additionally, spring of this mechanism released grip.

In the fifth test, the fuse No. 4 was fired again, when its brass lock was exchanged for duralumin lock. However, similarly to the fourth test the spring of its time mechanism released grip and the time mechanism didn't move. The driving lock of the rotor functioned properly.

In the sixth test the fuse No. 5 was fired. All its locks unlocked correctly except for the time mechanism lock, which in consequence blocked the gear.

After analyzing the results, all spring grips of the time mechanisms were improved and next four tests of firing to pieces of fabric were completed.

During these tests, only one of four fuses functioned properly. In remaining fuses, the locks of time mechanisms returned again to primary safety position blocking subsequent movement of the time mechanisms. This showed that only the elements to be improved are locks of time mechanisms for the fuse to be armed according to assumptions. Improvement of lock function may be achieved through: narrowing down the value of fitting tolerance of its base, improving the shape of butting face (elimination of edge radius on butting face of the lock) and forcing skewed position of lock in relation of the whole axis in which it is placed after firing.

It should be emphasized that tested fuses require, to full arming, action of two overloads in succession during firing. These overloads occur in precisely defined time (intervals) to be able to unlock appropriate locks protecting the fuse. These time intervals take into account dispersion of burning time of pyrotechnic elements such as pyrotechnic delayer transmitting fire impulse from start explosive charge to the rocket propulsion and work time of rocket propulsion. Unlocking of safety lock is influenced by characteristics of rocket propulsion thrust, which is the change the overload and the thrust in time. The dispersion of pyrotechnic delayer functioning amounts to maximum 0.3 s, but time dispersion of burning of rocket propulsion fuel amounts to ~0.25 s. Time intervals of overloads have been taken into consideration during designing of fuse mechanism, especially during designing the time mechanism, which fulfils two important functions. Firstly, protecting the fuse against premature arming and secondly, keeping specific elements in appropriate position until second overload occurs. Accurate function of fuses during dynamic fire tests confirms that kinetic systems of fuse mechanisms are working correctly. However, precise kinetic analysis illustrated on the graph is required in the future.

Electronic elements show resistance against the overloads occurred in all tests. Electronic assemblies, tested after firing, functioned correctly, which means that electric output impulse voltage, its amplitude and delay time, are with in assumed value interval. It should also be emphasized that both mechanical and electronic elements met requirements in relation to resistance against overloads occurring during the shot (2600 g). Two constructional elements should be corrected: the spring grip of time mechanism because time mechanism shouldn't release grip and also lock of time mechanism, which shouldn't return to protected position after firing, when the first overload occurs and process of fuse unlocking starts.

4. Conclusions

Preliminary tests on arming the fuses showed that:

- mechanical and electronic elements perform requirements in relation to resistance against overloads (2600 g) occurred during the shot from grenade launcher RPG-7,
- electronic systems, tested after fire, functioned correctly, that is electric output impulse voltage, its amplitude and delay time, are within assumed value interval,
- duralumin plunger, which interlocked and moved a rotor, should have a mass of 0.55 g,
- dimensions and mass of springs and locks were correctly defined,
- improved spring grip of time mechanism fulfilled requirements in relation to reliability of spring grip blocking, because the spring didn't release grip of gear axis during firing tests,
- the construction of time mechanism lock should be corrected, so that, it will not return to armed position after shooting (after occurrence of first overload operating), what may be achieved by narrowing working tolerance field its base and through inputting bevels on the surface, which is pushed by spring,
- to specify time intervals of fuse arming it is advisable to determine the rocket propulsion characteristics,
- it is necessary to do a precise kinetic analysis of mechanisms in the future work on the integrated fuse.

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